CLAIMS

What is Claimed is:

1. A method for selectively providing rear-wheel steering for a vehicle backing-up a trailer, said method comprising:

determining a steering angle of the vehicle;

determining a speed of the vehicle;

determining a measured hitch angle between the vehicle and the trailer;

calculating an equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position;

calculating a pseudo-equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position at a maximum rear-wheel steering input;

determining whether a predetermined relationship exists between the measured hitch angle, the equilibrium hitch angle and the pseudo-equilibrium hitch angle; and

providing the rear-wheel steering of the vehicle if the predetermined relationship does exist.

2. The method according to claim 1 wherein determining whether the predetermined relationship exists includes determining how close the measured hitch angle is to the equilibrium hitch angle and the pseudo-equilibrium hitch angle, determining a rate of change of the measured hitch angle, and determining whether the measured hitch angle is converging towards or away from the equilibrium hitch angle and the pseudo-equilibrium hitch angle.

3. The method according to claim 2 wherein determining whether the predetermined relationship exists includes determining the orientation of the steering angle of the vehicle and determining whether the measured hitch angle is within a range set by the equilibrium hitch angle and the pseudo-equilibrium hitch angle by a predetermined amount.

4. The method according to claim 1 wherein calculating the equilibrium hitch angle includes calculating the equilibrium hitch angle as:

$$\overline{\theta}_{eq} = \tan^{-1}(\tfrac{y}{x})$$

where,

$$x = h - \frac{L_1 \tan\delta_r}{\tan\delta_f - \tan\delta_r},$$

$$y = \frac{YL_2 x}{Y^2 - x^2} + \frac{x^2}{Y^2 - x^2}\sqrt{Y^2 + L_2^2 - x^2}\text{, and}$$

$$Y = \sqrt{\left(\frac{L_1}{\tan\delta_f - \tan\delta_r} + \frac{T}{2}\right)^2 + \left(h - \frac{L_1 \tan\delta_r}{\tan\delta_f - \tan\delta_r}\right)^2 - L_2^2}$$

5. The method according to claim 1 further comprising removing the rear-wheel steering if the predetermined relationship does not exist when the rear-wheel steering is being provided.

6. The method according to claim 5 wherein removing the rear-wheel steering includes determining the difference between a current rear-wheel angle command and a previously stored rear-wheel angle command and removing the rear-wheel steering if the difference is less than a predetermined value.

7. The method according to claim 5 wherein removing the rear-wheel steering includes determining how close the measured hitch angle is to the equilibrium hitch angle and the pseudo-equilibrium hitch angle.

8. The method according to claim 7 wherein removing the rear-wheel steering includes determining the orientation of the steering angle of the vehicle and determining whether the measured hitch angle is within a range set by the equilibrium hitch angle and the pseudo-equilibrium hitch angle by a predetermined amount.

9. The method according to claim 1 wherein providing the rear-wheel steering includes providing proportional and derivative control of the rear-wheels of the vehicle.

10. The method according to claim 1 wherein providing the rear-wheel steering includes calculating a current rear-wheel angle command and determining whether the current rear-wheel angle command is less than a previous rear-wheel angle command by a predetermined amount.

11. The method according to claim 10 wherein providing the rear-wheel steering includes providing the current rear-wheel angle command if the current rear-wheel angle command is less than the predetermined amount.

12. The method according to claim 10 wherein providing the rear-wheel steering includes setting the current rear-wheel angle command to the predetermined amount if the current rear-wheel angle command is greater than the predetermined amount.

13. A method of selectively providing rear-wheel steering for a vehicle backing-up a trailer, said method comprising:

determining a steering angle of the vehicle;

determining a speed of the vehicle;

determining a measured hitch angle between the vehicle and the trailer;

calculating an equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position;

calculating a pseudo-equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position at a maximum rear-wheel steering input;

determining whether a predetermined relationship exists between the measured hitch angle, the equilibrium hitch angle and the pseudo-equilibrium

hitch angle, wherein the predetermined relationship includes determining the orientation of the steering angle of the vehicle, determining whether the measured hitch angle is within a range set by the equilibrium hitch angle and the pseudo-equilibrium hitch angle, determining a rate of change of the measured hitch angle and determining whether the measured hitch angle is converging towards or away from the equilibrium hitch angle and the pseudo-equilibrium hitch angle;

providing rear-wheel steering of the vehicle if the predetermined relationship does exist; and

removing the rear-wheel steering if the predetermined relationship no longer exists when the rear-wheel steering is being provided.

14. The method according to claim 13 wherein removing the rear-wheel steering includes determining the difference between a current rear-wheel angle command and a previously stored rear-wheel angle command and removing the rear-wheel steering if the difference is less than a predetermined value.

15. The method according to claim 13 wherein removing the rear-wheel steering includes determining how close the measured hitch angle is to the equilibrium hitch angle and the pseudo-equilibrium hitch angle.

16. The method according to claim 15 wherein removing the rear-wheel steering includes determining the orientation of the steering angle of the vehicle and determining whether the measured hitch angle is within the range set by the equilibrium hitch angle and the pseudo-equilibrium hitch angle by a predetermined amount.

17. The method according to claim 13 wherein providing the rear-wheel steering includes providing proportional and derivative control of the rear-wheels of the vehicle.

18. The method according to claim 13 wherein providing the rear-wheel steering includes calculating a current rear-wheel angle command and determining whether the current rear-wheel angle command is less than a previous rear-wheel angle command by a predetermined amount.

19. The method according to claim 18 wherein providing the rear-wheel steering includes providing the current rear-wheel angle command if the current rear-wheel angle command is less than the predetermined amount.

20. The method according to claim 18 wherein providing the rear-wheel steering includes setting the current rear-wheel angle command to the predetermined amount if the current rear-wheel angle command is greater than the predetermined amount.

21. The method according to claim 13 wherein calculating the equilibrium hitch angle includes calculating the equilibrium hitch angle as:

$$\overline{\theta}_{eq} = \tan^{-1}\left(\frac{y}{x}\right)$$

where,

$$x = h - \frac{L_1 \tan\delta_r}{\tan\delta_f - \tan\delta_r},$$

$$y = \frac{YL_2 x}{Y^2 - x^2} + \frac{x^2}{Y^2 - x^2}\sqrt{Y^2 + L_2^2 - x^2}\ , \text{ and}$$

$$Y = \sqrt{\left(\frac{L_1}{\tan\delta_f - \tan\delta_r} + \frac{T}{2}\right)^2 + \left(h - \frac{L_1 \tan\delta_r}{\tan\delta_f - \tan\delta_r}\right)^2 - L_2^2}$$

22. A system for selectively providing rear-wheel steering for a vehicle backing-up a trailer, said system comprising:

a steering angle sensor for determining a steering angle of the vehicle;

a speed sensor for determining a speed of the vehicle;

a hitch angle sensor for measuring a hitch angle between the vehicle and the trailer; and

a controller for selectively providing the rear-wheel steering to the vehicle if a jackknife condition is probable, said controller calculating an equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position, calculating a pseudo-equilibrium hitch angle between the vehicle and the trailer that is a steady-state hitch angle position at a maximum rear-wheel steering input, determining whether a predetermined relationship exists between the measured hitch angle, the equilibrium hitch angle and the pseudo-equilibrium hitch angle, and providing the rear-wheel steering to the vehicle if the predetermined relationship does exist.

23. The system according to claim 22 wherein the controller determines how close the measured hitch angle is to the equilibrium hitch angle and the pseudo-equilibrium hitch angle, determines a rate of change of the measured hitch angle, and determines whether the measured hitch angle is converging towards or away from the equilibrium hitch angle and the pseudo-equilibrium hitch angle to determine whether the predetermined relationship exists.

24. The system according to claim 23 wherein the controller determines the orientation of the steering angle of the vehicle and whether the measured hitch angle is within a range set by the equilibrium hitch angle and the pseudo-equilibrium hitch angle by a predetermined amount to determine if the predetermined relationship exists.

25. The system according to claim 22 wherein the controller removes the rear-wheel steering if the predetermined relationship does not exist when the rear-wheel steering is being provided.

26. The system according to claim 25 wherein the controller determines the difference between a current rear-wheel angle command and a previously

stored rear-wheel angle command and removes the rear-wheel steering if the difference is less than a predetermined value.

27. The system according to claim 26 wherein the controller determines how close the measured hitch angle is to the equilibrium hitch angle and the pseudo-equilibrium hitch angle when it determines that the predetermined relationship does not exist.

28. The system according to claim 27 wherein the controller determines the orientation of the steering angle of the vehicle and whether the measured hitch angle is greater than the equilibrium hitch angle and close to the pseudo-equilibrium hitch angle by a predetermined amount when it determines that the predetermined relationship does not exist.

29. The system according to claim 22 wherein the controller provides proportional and derivative control of the rear-wheels of the vehicle.

30. The system according to claim 22 wherein the controller calculates a current rear-wheel command and determines whether the current rear-wheel command is less than a previous rear-wheel angle command by a predetermined amount.

31. The system according to claim 30 wherein the controller sets the rear-wheel steering to the current rear-wheel command if the current rear-wheel command is less than the predetermined amount.

32. The system according to claim 30 wherein the controller decreases the current rear-wheel command the predetermined amount if the current rear-wheel angle command is greater than the predetermined amount.